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Form Factor and Stability of API Bullet T39 Fired From Shortened Caliber 0.60
  Barrels
    Hitchcock, H. P.
        Aberdeen Proving Ground, Ballistic Research Lab., Md.
      (Same)

March 447 Confd'l   U.S.   Eng.   8   tables

The effects of shortening the barrel of the caliber 0.60 machine gun for use in aircraft was investigated,
and consideration was given to the ballistics of the API Bullet T 39 fired from two 0.60 cal. Mann barrels
shortened from 60 in. to 25.6 and 33.1 in. The principal ballistic effects of shortening the barrel are a
reduction of muzzle velocity, a slight increase of formfactor, and a decrease of stability factor. If the
API Bullet T39 were fired from one of the short barrels aimed forward in an airplane flying at sea level
with an airspeed of 600 mph, it would be unstable. However, this objection could be overcome by increas-
ing the twist of the rifling, and a 25.6 in. barrel with a pitch of 15.4 in. or a 33.1 in. barrel with a pitch
of 16.5 in. would produce the same stability factor at sea level with 600 mph airspeed as a 60 in. barrel
with a pitch of 16 in.

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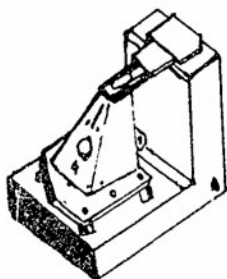
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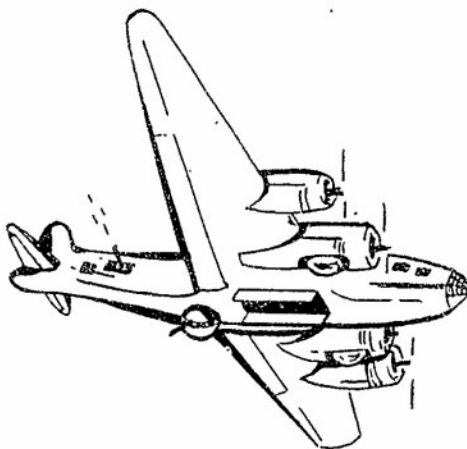
MEMORANDUM
REPORT NO. 456

FORM FACTOR AND STABILITY OF API BULLET T39 FIRED
FROM SHORTENED CALIBER 0.60 BARRELS

BY

H. P. HITCHCOCK

19 March 1947

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 456

Hitchcock/cmh
Aberdeen Proving Ground, Md.
19 March 1947

Exterior Ballistics Laboratory
Problem No. E-172

FORM FACTOR AND STABILITY OF API BULLET T39 FIRED FROM SHORTENED CALIBER 0.60 BARRELS

Abstract

The API Bullet T39 was fired from two caliber 0.60 Mann barrels shortened from 60 inches to 25.6 and 33.1 inches. The main ballistic effects are indicated by the following table.

Length of Barrel	Muzzle Velocity	Form Factor	Stability Factor	
			Normal	With 600 mph Head Wind at Sea Level
in.	fps	i_7		
60	3550	1.26	1.79	1.15
33.1	3090	1.27	1.61	0.97
25.6	2820	1.31	1.45	0.84

1.   OBJECT: The effects of shortening the barrel of the caliber 0.60 machine gun for use in aircraft is being investigated. The Small Arms Branch of the Arms and Ammunition Division has found that ammunition fired at vertical targets from short barrels is as accurate as from a standard length barrel. The Ordnance Engineering Laboratory of the Ballistic Research Laboratories is preparing to test the muzzle blast with short barrels. This report is concerned with the ballistics of bullets fired from the short barrels.[1]

2.   GUNS: The normal caliber 0.60 Mann Barrel is 60 inches long and is rifled with a pitch of 18 inches. In this test, two barrels were used:

> No. 6-2, 25.6 inches long,
> No. 6-3, 33.1 inches long.

Since these barrels were too short to fit in the Frankford Arsenal Machine Rest, the Machine Shop fitted sleeves over the muzzles, extending a few inches beyond the muzzle face.

3.   AMMUNITION: Some caliber 0.60 Armor-piercing Incendiary Cartridges I39 were taken from FA lot 10. Some similar cartridges of other lots have previously been fired for time of flight from 60-inch Mann Barrel No. 300 with a 17-inch pitch of rifling[2], and for yaw from 60-inch notched Mann Barrel No. 60 with an 18-inch pitch.[3] The physical characteristics of the I39 bullet are:[4]

Weight (standard)	1140 grains
Center of gravity to base	1.765 cal
Axial moment of inertia	47.9 gr.in^2
Transverse moment of inertia	490.1 gr.in^2

4.   TIME-OF-FLIGHT FIRINGS: The time-of-flight firings were conducted at Michaelsville on 14 February 1947.[5] The velocity 78 feet from the muzzle was measured by an electronic counter connected to two photo-electric screens. The time of flight was measured by another electronic counter connected to the first photo-electric screen and a wire mesh screen at a range of 1000 yards. The form factors were computed from the velocities and times of flight (see Table I).

5.   FORM FACTORS: The velocities, of course, are lower than those obtained with the 60-inch barrel; the form factors are slightly higher.[6] The average values are shown here:

Length of barrel	in.	25.6	33.1	60
Instrumental velocity	fps	2788	3053	–
Avg. velocity over range	fps	2202	2452	–
Muzzle velocity	fps	2822	3088	3550
Form factor	i_7	1.314	1.272	1.26
Ballistic coefficient	C_7	.344	.356	.358
Retardation coef. (at MV)	per ft.	.000,160	.000,146	–

6. YAW FIRINGS: The yaw firings were conducted at the Small Arms Range on 12 February 1947.[5] Five rounds were fired from each barrel thru 15 photographic paper screens, which were placed at 5-foot intervals in each of three groups:

<div style="text-align:center">

10 to 35 feet,

90 to 115 feet,

175 to 200 feet.

</div>

7. YAW: The first maximum yaw varied from 0 to 10 degrees (see Table II). The maximum yaw damped rapidly: in the last group of screens, the largest yaw was 6 degrees. The minimum yaw varied from 0 to 1.2 degrees.

8. PRECESSION: The rate of precession calculated from the moments of inertia and the pitch of rifling is 0.06516 semi-revolution per foot. On all rounds with yaws greater than 2 degrees, the observed orientations were in good agreement with this rate.

9. STABILITY: The stability factors of the bullets fired from these short barrels at muzzle velocities of 2820 and 3090 feet per second (Table III) are less than that of the bullets fired from a 60-inch barrel at 3550 feet per second.[7] The average values of the stability factor and the corresponding moment coefficient and period of yaw are as follows:

Length of barrel	in.	25.6	33.1	60
Stability factor:				
Normal		1.450	1.606	1.79
With 600 mph head wind at sea level		0.84	0.97	1.15
Moment coefficient	K_M	1.50	1.35	1.59
Period (normal)	ft	27.5	25.0	23.1

10. CONCLUSION: The principal ballistic effects of shortening the caliber 0.60 barrel are a reduction of muzzle velocity, a slight increase of form factor, and a decrease of stability factor. If the API Bullet T39 were fired from one of the short barrels aimed forward in an airplane flying at sea level with an air speed of 600 miles per hour, it would be unstable. However, this objection could be overcome by increasing the twist of rifling: a 25.6-inch barrel with a pitch of 15.4 inches, or a 33.1-inch barrel with a pitch of 16.5 inches would produce the same stability factor at sea level with a 600-mile-per-hour air speed as a 60-inch barrel with a pitch of 18 inches.

H. P. Hitchcock

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APG: BRL MR 266, 1945.

LIST OF TABLES

TABLE I

Velocities, Times of Flight, and Form Factors

Cal .60 Maxim Barrels C - 2 (25.8" long) and C - 3 (33.1" long)

Fired at Aberdeenville 14 Feb 47

1140 - gr API Bullet T39

Muzzle to 1st P.E. screen		25.0 ft
1st to 2nd P.E. screen		100.0 ft
1st P.E. screen to wire mesh screen		2972.3 ft

Barrel	Round	Air Temp.	Air Density	Range Wind	Velocity	Time of Flight*	Ball. Coef.	Form Factor
No.	No.	F	ratio	fps	fps	sec	C_7	i_7
C - 2	3	48	1.045	- 10.2	2800	1.38869	.3519	1.336
	4	48	1.045	- 10.2	2770	1.42005	.3410	1.327
	5	48	1.045	- 10.2	2772	1.41347	.3452	1.310
	7	48	1.045	- 10.2	2737	1.40919	.3417	1.324
	8	48	1.045	- 10.2	2794	1.41354	.3398	1.331
	9	48	1.045	- 10.2	2798	1.39246	.3499	1.295
	10	48	1.045	- 10.2	2786	1.40865	.3426	1.320
	11	48	1.045	- 10.2	2800	1.39354	.3481	1.300
	12	48	1.045	- 10.2	2807	1.39829	.3413	1.325
	13	48	1.045	- 10.2	2777	1.41426	.3423	1.322
	Mean				2788			1.314
	P.E. of mean							.003
C - 3	16	49	1.043	- 10.1	3070	1.25024	.3515	1.287
	17	49	1.043	- 11.3	3040	1.25949	.3564	1.269
	20	49	1.043	- 15.1	3054	1.25575	.3546	1.276
	21	49	1.043	- 11.3	3034	1.26597	.3528	1.282
	22	49	1.043	- 11.4	3053	1.25629	.3553	1.279
	23	49	1.043	- 19.9	3058	1.25016	.3591	1.259
	24	49	1.043	- 17.1	3092	1.23590	.3573	1.268
	25	49	1.043	- 19.9	3035	1.26385	.3564	1.266
	26	49	1.043	- 14.5	3037	1.26093	.3571	1.267
	27	49	1.043	- 16.0	3060	1.25163	.3560	1.271
	Mean				3053			1.272
	P.E. of mean							.002

* From 1st P.E. screen to wire mesh screen.

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TABLE II

Stability Firing Data

Cal .60 Mann Barrels 6 - 2 (25.6" long) and 6 - 3 (33.1" long): twist 1/18"

API Bullet T39

Barrel	Round	Time 1947 Feb	Air Temp.	Air Density	Maximum Yaw deg.			Muzzle to Min. Yaw ft		No. of Periods	Precession φ'/π
No.	No.	h m	F	ratio	First	Middle	Last	First	Last		semi-rev/ft
6 - 2	1	1035	34	1.090	2.0	?	0.4	32	187	5	.06516 ?
	2	1046	34	1.090	7.1	3.5	2.5	33	185	5	.06516
	3	1058	34	1.089	7.1	2.5	2.0	35	182	5	.06516
	4	1108	35	1.089	9.2	8.4	5.4	30	200	6	.06516
	5	1117	35	1.089	7.6	3.2	?	35	183	5	.06516
6 - 3	6	1314	40	1.077	7.0	5.1	Hit frame at 105'				
	7	1320	40	1.077	4.2	2.4	1.6	32	112	3	.06516
	8	1327	40	1.077	9.9	8.1	?	30	188	6	.06516
	9	1335	40	1.077	0.0	0.0	0.0				
	10	1343	40	1.077	1.6	0.8	0.0	32	112	5	.06516

Table III

Stability Results

Cal. 60 Mamm Barrels 6 - 2 (25.6" long) and 6 - 3 (33.1" long) Twist 1/18")

BULLET, API T59

Barrel	Round	Yaw Screen Factor * $\frac{\Sigma(\delta/\alpha)^2}{n}$	Period ft. Avg Without Screens**		Stability Factors		
					Without Screens	At Muzzle	At normal Air Dens.
No.	No.		L_a	L_c	s_c	s_o	s_ρ
6 - 2	1	.592	31.00	30.61	1.336	1.290	1.406
	2	.567	30.40	30.02	1.354	1.308	1.426
	3	.623	29.40	28.99	1.389	1.341	1.460
	4	.752	28.33	27.83	1.437	1.385	1.508
	5	.493	29.60	29.27	1.379	1.332	1.451
	Mean						1.450
	P.E. of mean						.012
6 - 3	7	.716	26.67	26.19	1.523	1.491	1.606
	8	.639	26.33	25.91	1.540	1.492	1.607
	10	.714	26.07	26.20	1.522	1.490	1.605
	Mean						1.606
	P.E. of mean						.0004

* δ is the yaw, and α the maximum yaw, at each screen between the first and last minimum yaws; n is the number of periods between them.

** Yaw screen constant 0.565 (from firings in 60" barrel).